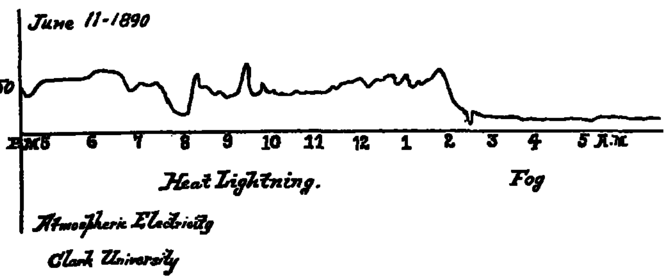
excellent in the afternoon may weaken materially during the night. I found it advisable at Clark University, some years ago, to keep an extra set of dry, clean Mascart table insulators always in readiness. Almost every morning, after tests, the insulators were exchanged with those under the collector which stood in a wooden shelter, projecting from a second-story window and exposed to the weather. Indeed, a very good hygroscope might be devised upon this variation of insulation with humidity. The accompanying diagram shows the potential curve obtained with a photographic Mascart electrometer and outfit. It is interesting to note the fall in



the potential with the occurrence of fog. This may have been a natural fall, for in the diurnal curve a minimum occurs about the time of sunrise; or it may have been, and in all probability was, brought about by the decreasing insulation. There are, however, different kinds of fog; so also, do we find different values of the potential at times of fog, and to some degree the electrometer takes note of the difference. Generally with fog, haze, and smoke there is a rapid fall from high positive to low positive or negative values. Dust whirls, because of frictional effects, give marked disturbances. But fogs, after fine drizzling rain, as a rule, give high positive values. On October 4, 1886, at the top of the Washington Monument during a light and seemingly dry fog, I obtained potentials of over 700 volts, and had no difficulty in drawing small sparks. Simultaneous observations were made at a station 450 feet lower, and potentials of 140 volts, on the average, were obtained. These were high values for this elevation and exposure. On the day following, about the same in general character except for the fog, the potential values were but one-half the former *at both stations.*

The great problem then in atmospheric electricity has been to preserve a high insulation in the apparatus. There is another question, viz, the breaking down of the air itself. For example, after the passage of an electric current, as in the case of a flash of lightning, the particular path is defective thereafter and allows easy escape of high surface charges. Then again, as Hallwachs, Elster, and Geitel, and others have shown, a negatively charged surface will discharge into air under the influence of ultraviolet light. What is of significance to the meteorologist, in these investigations, is the apparent relation, as Schuster points out,[1] "between the ultraviolet radiations and the amount of aqueous vapor present in the air."

Much could be said concerning these potential falls and the accompanying phenomena; but the object of the present paper is rather to trace the dependence of the industrial applications of electricity upon atmospheric conditions. More particularly the point is that electrical development is reaching a limit because of unsuitable insulation. In other words, so rapid has been the advance in the use of high potentials that the electrical engineer to-day is very nearly in the position of the experimenter in atmospheric electricity. He has to deal with potentials of enormously high voltage, and realizes that the successful transmission of the same will be determined largely by the insulation, and this in turn is determined by the weather.

Electrical journals are largely filled at present with accounts of the transmission of electrical energy from mountain streams to towns and cities many miles distant. For example, a power company with a plant in the mountains, contracts to deliver at a city 25 miles away, a three-phase alternating current of 2,500 volts pressure. Through the agency of step-up transformers the potential is sent up to 11,000 volts and transmitted thus, mile after mile in the open country. Reaching the city, it is transformed down, first to 2,000 or 2,500 and then again to 100 or less. In reading the description of such a system, one is attracted first by the step-up transformers. These cast iron, oil-filled, water-jacketed boxes are more or less at the mercy of the weather. Secondly, the large copper wires carrying the high potentials, must be very well insulated. As we read of triple-petticoated insulators, we recall the earlier struggles of the investigator of atmospheric electricity.

In further applications of high potential electricity then, there will be limitations because of atmospheric conditions. Will the meteorologist, with his knowledge of the physics of the air, come to the rescue and point out the proper directions for experiment with the aim of overcoming present difficulties?

That the views set forth above are not exaggerated, the following editorial from the Journal of Electricity of May, 1897, will prove:

* * * Science has well in hand the control of lightning, of static effects, and of the mechanical features that give permanence, safety, and reliability to overhead transmission lines, nor is difficulty experienced in the handling of line voltages at present used, but the barrier—thus far insuperable—to the employment of higher potentials is, as stated, embodied in the insulator alone.

Climate exerts a potent influence on the reliability of insulators, and so great is this influence that to it rather than to the insulator itself may be attributed the existing limitations to the commercial use of higher voltages. In addition to being a practically perfect nonconductor, the insulator should be wind, rain, snow, sleet, dust, and insect proof. Its reliability as a sure preventive against all possible sources of trouble should be absolute, for if susceptible to breakdowns, its weakness necessitates the duplication of the transmission lines that no interruption to service may occur in making repairs. The saving in copper which will result from the invention of a perfect insulator would be twofold in that it would enable the use of higher voltages and require only a single transmission line. Truly may it be said that unlimited reward awaits the inventor of a perfect high-tension insulator.

ATMOSPHERIC ELECTRICITY: ITS ORIGIN, VARIATIONS, AND PERTURBATIONS.

By Prof. MARCEL BRILLOUIN, of the École Normale Supérieure of Paris.

[Translated from the Revue Générale des Sciences pures et Appliquées, August 30, 1897; and from Ciel et Terre, October 1, 1897.]

The origin of atmospheric electricity still remains quite unknown; the suggested theories all rest upon properties that are hypothetical or even contradictory to experience. It has long seemed to me that the action of the ultraviolet radiations from electrified bodies furnishes an entirely satisfactory explanation, assuming only that ice acts in the same way as metals; as to this latter assumption I was able to satisfy myself during this past winter.

The following lines give a brief synopsis of this physical theory of the electric phenomena of the atmosphere:

1.—In 1887 Herz discovered that the electric discharge occurs more easily under the action of ultraviolet light than in the dark. In 1888 Wiedemann and Ebert showed that this action takes place at the "cathode" or negative electrode; that its effect is a maximum when the air is under a pressure of about 300 millimeters of mercury; according to Arrhenius the maximum occurs when the air is under a pressure of 6 millimeters, but according to Stoletow, at a pressure that varies very nearly in proportion to the intensity of the electric field.

[1] Lecture before Royal Institute, February 22, 1895.

An attentive study of this action has shown that *all metal surfaces charged with negative electricity lose this electricity when they are exposed to ultraviolet radiations, however feeble the negative charge may be.*

The action upon positive electricity is null.

M. Rhigi and M. Stoletow have even been able to make use of this action for the purpose of measuring differences of potential at the very point of contact of two electrodes.

2.—M. Buisson who has tested this most delicate action of the ultraviolet light has, at my request, made a series of experiments upon ice as compared with zinc.

A beam of ultraviolet light (electric arc between aluminum electrodes) traverses a perforated brass plate that is positively electrified and then falls upon a block which forms the negative armature of the condenser. This block of ice rests upon a metallic plate having insulating feet and is connected with an electrometer. At first the ice and the electrometer are put in electric communication with the ground, whereby they are brought to the same negative potential and then this connection is broken. As soon as the beam of ultraviolet light is thrown upon the ice the needle of the electrometer moves and shows that the block of ice loses its negative electricity until the potential of the ice and of the brass plate are equal.

The action upon a block of *dry* ice, when just taken from a refrigerating mixture, is very intense (of the tenth to the twentieth order relative to the action on zinc). As soon as the surface of the block begins to melt the action of the ultraviolet light decreases very much; finally, when the water resulting from melting covers the whole illuminated surface of the block the loss of negative electricity becomes inappreciable.

Such are the results that were obtained during this winter (1896–97) by M. Buisson in the physical laboratory of the École Normale at Paris.

Ice is very sensitive to the ultraviolet radiations; water is nonsensitive.

3.—When we consider the unquestionable influence of the diminution of pressure upon the action of light and on the absorption of the ultraviolet solar light by our atmosphere, these laboratory results transform my hypothesis as to the origin of atmospheric electricity into an experimental theory worthy of publication.

If, at any time whatever, an electric field exists in the atmosphere, the ice needles of the cirrus clouds become electrified by induction, positively at one end, negatively at the other. If now, the negative extremities of these ice needles should receive ultraviolet solar radiations, the needles thus illuminated would lose all their negative charge and remain electrified *positively.*

The neutral or negative state of the cirri is unstable; every cirrus cloud illuminated by the sun becomes positive.

4.—Furthermore, experience has shown that the air thus illuminated by sunlight remains a good insulator (contrary to what occurs with the Roentgen rays). In the laboratory experiments, where the positive conductor is very near to the negative conductor, the transportation of electricity by the movement of the air is rapid. In the atmosphere it will be quite otherwise.

If the negative electricity lost by the ice needles is deposited in the surrounding air, then the cloud, as a whole, appears positive when the ice needles become separated from the surrounding air.

The neutral state of the air is unstable. The air which traverses a region where illuminated cirri are formed becomes negative. The neutral air into which a positive cirrus cloud has evaporated into invisibility has become positive.

In the formation of cirri by mixture there frequently occur independent movements of contiguous masses of air—some cloudy and others clear. The negative air will then separate from the positive cirrus.[1]

If the mass of negative air descends, and if continuing negative (for the electricity can not be destroyed) it reaches the cultivated soil, the innumerable points of the blades of grass and leaves will facilitate the discharge of electricity between the earth and the air. Hence, *the soil of a continent is charged negatively by exchange with the air.*

At the surface of the ocean there occurs nothing similar to this; the descending air remains negative; it becomes saturated with vapor, but when this vapor ascends and by expansion is condensed into fine droplets these little drops, like fine points, borrow their electric charge from the air. Hence, *the cumuli formed by expansion over the oceanic regions are negative.*

At the surface of the ground no direct action of the ultraviolet radiations is perceived, both because these radiations scarcely reach it, and because there is no appreciable amount of water there, and because the pressure of the air is high.

5.—It seems useless to dwell upon the characteristics of the diurnal variation of atmospheric electricity and complications that the transportation of electrified air may produce. The influence upon thunderstorms is evident; the same gust of wind that brings rain and showers at night brings thunderstorms at the close of the daylight, when the solar action has electrified the cirrus clouds, and when convection has carried off the negative air. The slowness of this convection also explains the two or three days of threatening weather which, in our climate (of France), generally precede the storm itself.[2]

In regions or seasons where the air is nearly calm (as at the boundary of the cone of the circumpolar shadow of the earth during the winter season) there is so little convection that the cirrus, electrified positively throughout its entire mass during the daylight, remains surrounded by negative air. As soon as the darkness of nighttime prevails the stable condition changes; the electric discharge between the negatively electrified air and the positively electrified needles of ice permeates the whole mass of the cloud. This explanation harmonizes perfectly with all the details of the aurora borealis; it applies also to the luminous clouds sometimes observed in Europe and to the diffuse light observed during summer evenings and called *heat lightning.*[3]

6. Finally, the mechanism of the action of solar disturbances, as seen from this point of view, becomes very simple. Every variation of brilliancy in the ultraviolet light from the sun has an immediate action upon auroras and atmospheric electricity wherever cirrus clouds exist; but its action on thunderstorms may be retarded for several days wherever the cumuli existing below the cirri are neutral or nearly so. The necessity of having cirrus clouds, either preexisting or in process of formation, and of having cumulus clouds localizes this action of ultraviolet rays upon thunderstorms in a manner that varies with the general meteorological conditions.

The importance of the perturbations that are produced in the earth's atmosphere has no relation to the apparent importance of the solar spots and faculæ, but depends exclu-

[1] See memoir on Winds and Clouds by M. Brillouin, to be published in the Annals of the Central Meteorological Bureau of France for 1898; see the summary on page 437 of this number of the MONTHLY WEATHER REVIEW. This idea that positive cirrus and negative air will separate from each other needs to be substantiated by some very convincing experiments.—C. A.

[2] In the United States these days of threatening weather represent more properly the movement of the whole disturbance eastward; at other times they represent the gradual accumulation and spread eastward of thickening stratus haze.—C. A.

[3] There is no longer any doubt that the so-called *heat lightning* is generally produced by distant thunderstorms whose lightning illuminates the sky.—A. Lancaster. [The visibility of auroral beams in daylight is not explained by Brillouin.—C. A.]

sively upon the intensity of the ultraviolet radiation that is transmissible through our atmosphere. Thus, the faculæ, and especially the spots seen with the naked eye, are only imperfect indicators, and it is greatly to be desired that observations such as those of M. Deslandres[1] should be organized and published systematically.

7.—Other phenomena, such as the breaking up into droplets of water falling upon any obstacle, have for some years past been mentioned as having to do with the production of atmospheric electricity. I believe that they play only a secondary rôle as a disturbing action, and that the fundamental rôle is that which I have described above. In general:

Atmospheric electricity is maintained by the action of ultraviolet solar radiations upon the ice needles of the cirrus clouds.

To the same cause is due the necessary initial electric field that is inevitably produced by the relative displacements of the upper masses of the atmosphere in relation to the magnetized terrestrial globe.

THE AREA OF HEAVY RAINFALL IN THE SOUTHERN APPALACHIANS.

By BARRY C. HAWKINS, Voluntary Observer, Weather Bureau. Station, Horse Cove; Post Office, Highlands, Macon Co., N. C. (dated November 3, 1897).

For several years it has been well known by meteorologists that there exists in the southern Blue Ridge Mountains a region where the annual total of rainfall is abnormally large, at least 70 inches, or more. The literature of the subject is about as follows: Numerous brief references have appeared, the most extended being an article in the American Meteorological Journal (May, 1894, Vol. XI, pp. 6–10) by Mr. A. J. Henry, Chief of the Records Division, Weather Bureau. A brief general statement regarding this area and its probable cause is to be found in Prof. M. W. Harrington's ideal and exhaustive report on the rainfall of the United States, published as Bulletin C by the Weather Bureau. Other briefer references are as follows: A statement concerning the portion of the area in North Carolina in the most excellent report on the Climatology of North Carolina, published by the North Carolina State Weather Service and prepared by Mr. C. F. von Herrmann, now director of the North Carolina Section of the Climate and Crop Service, Weather Bureau; also, in Georgia, A Hand Book, issued by the Department of Agriculture of the State of Georgia. It is not my intention to attempt to give reasons for this area of heavy rainfall, but merely to present a comprehensive summary of what is known concerning the geographical distribution of the rainfall, and also the general statistics, including the distribution in the different months.

The area included is the extreme southern Blue Ridge, and covers portions of extreme northeastern Georgia, extreme western South Carolina, and southwestern North Carolina. The counties included are as follows, it being understood that only certain portions in the case of nearly every county are referred to, the records being too few to define the limits more minutely. In the case of Macon County, N. C., it is certain that only the eastern part has an excessive rainfall. The counties marked by a dagger (†) are doubtful, it being only inferred that they are within the area.

North Carolina: Macon, Polk, Clay,† Jackson, Transylvania,† and Henderson.†

Georgia: Rabun, Habersham,† and Towns.†

South Carolina: Oconee, Pickens,† and northern Spartanburg.†

[1] Brillouin evidently refers to the numerous memoirs of Deslandres relative to the ultraviolet radiations from the sun, beginning with his first memoir on the ultraviolet spectrum of aqueous vapor and its relation to the dark lines in the solar spectrum, published in the Paris Comptes-Rendus for 1885, Vol. C, p. 854, and concluding with recent papers recording daily the condition of the sun as to the intensity of its ultraviolet radiations.—C. A.

The stations where records have been kept are as follows, those discontinued being marked with a star (*):

North Carolina: Macon County, Highlands, N. 35° 5', W. 83° 11', elevation, 3,817 feet; Horse Cove, N. 35° 0', W. 83° 6', elevation (estimated), 2,800 feet. Jackson County, Cashiers,* N. 35° 4', W. 83° 5, elevation, 3,812 feet. Polk County, Columbus* (now Skyuka), N. 35° 14', W. 82° 11', elevation, 3,000 feet.

Georgia: Rabun County, Rabun Gap,* N. 34° 55', W. 83° 20', elevation, 2,168 feet; Clayton, N. 34° 50', W. 82° 20', elevation, 2,100 feet.

The following stations in North Carolina may possibly be in the area: Henderson County, Hendersonville,* N. 35° 17', W. 82° 27', elevation, 2,167 feet; Flat Rock, N. 35° 15', W. 82° 25', elevation, 2,214 feet. Transylvania County, Brevard, N. 35° 15', W. 82° 45', elevation, 2,500 feet.

Over all the rainy region the annual total is 68 inches, or more. The following are the annual average total rainfalls (in inches) at stations where the data are at hand: Rabun Gap, 68.35 (nine years); Highlands, 76.29 (nine years); Horse Cove, 74.99 (five years); Cashiers, 78.50 (one year).

The distribution of the rainfall by months is very interesting. There is a well marked double maximum and minimum; the maximum is in February or March and the minimum in April or May for the first half of the year; the second maximum is in July or August and the second minimum in October or November.

The maxima at Highlands are: 9.64, in February, and a lesser maximum, 6.04, in September. The minima are: May, 4.19, and a second one, in October, 5.69. It is seen that the total for the wettest month is double that for the driest.

If other stations had long records for *the same term* of years, they would probably have similar features.

The record at Rabun Gap does not closely correspond with that at Highlands. The monthly and annual averages for three stations are given below, but there are several recent years of observations at Highlands which are not included:

Months.	Highlands (9 years).	Horse Cove (5 years).	Rabun Gap (9 years).
	Inches.	*Inches.*	*Inches.*
January	6.72	8.36	7.26
February	9.64	6.39	6.34
March	8.80	4.40	7.60
April	5.92	5.59	5.23
May	4.19	5.42	4.88
June	4.71	8.59	4.59
July	5.81	7.39	4.59
August	5.76	8.16	5.98
September	6.04	6.75	4.78
October	5.69	2.23	6.28
November	6.39	5.37	5.11
December	7.12	6.34	5.76
Annual	76.29	74.99	68.35

The average number of rainy days has been computed for the station at Horse Cove from a nine years' record. Some very interesting facts are shown. The number of rainy days annually is 134. This shows clearly that *rain does not occur any oftener than in regions where the fall is* 50 *inches or less, but that rains are heavier when they do come.* The monthly maximum is eighteen days in July; minimum, six days in October.

Surrounding the region of 68 inches, or more, there is a large area having a fall of 60 inches, or more, annually, and this area extends to the Gulf Coast; but this area of 60 inches does not come within the consideration of this paper. It is not believed that the area is continuous, as mentioned above, but that islands of heavy rainfall exist here and there on the uplands, with small areas of lighter rainfall on the lower lands, corresponding with the topography. I do not believe that any portions of the region having elevations of 1,500 feet or less are included in the area of 68 inches, or more, of